Developing attitudes towards science measures

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Abstract

In this study, we describe the development of measures used to examine pupils' attitudes towards science. In particular, separate measures for attitudes towards the following areas were developed: learning science in school, practical work in science, science outside of school, importance of science, self-concept in science and future participation in science. In developing these measures, criticisms of previous attitude studies in science education were noted. In particular, care was taken over the definition of each of the attitude constructs, and also ensuring that each of the constructs was unidimensional. Following an initial piloting process, pupils aged 11 to 14 from five secondary schools throughout England completed questionnaires containing the attitude measures. These questionnaires were completed twice by pupils in these schools, with a gap of four weeks between the first and second measurements. Altogether, 932 pupils completed the first questionnaire and 668 pupils completed the second one. Factor analysis carried out on the resulting data confirmed the unidimensionality of the separate attitude constructs. Also, it was found that three of the constructs, learning science in school, science outside of school and future participation in science, loaded on one general attitude towards science factor. Further analysis showed that all the measures showed high internal reliability (Cronbach $\alpha > 0.7$). A particular strength of the approach used in this study was that it allowed for attitude measures to be built up step-by-step, therefore allowing for the future consideration of other relevant constructs.

Introduction

Osborne *et al.* (2003) characterised students' attitudes towards studying science as an 'urgent agenda for research'. The main problem is a well-documented gap between needs and reality for the discipline of science. The needs relate to society having a greater requirement than ever for highly educated people in science to meet economic, environmental and technological challenges. The reality is a falling number of students choosing to pursue the study of science. This problem is a worry for governments all over the world and questions have been raised about what can be done to increase students' interest in science (for example, the consideration of the situation for physics in the European Union, Coughlan, 2000). Another problem, which is perhaps more relevant for science teachers on an everyday basis, is the relationship between attitudes and learning (Schibeci, 1984). Learning clearly has an affective component and developing positive attitudes is important for students' achievement.

Working with these problems requires a wide range of research. The contribution from the present study is the development of an instrument for measuring students' attitudes towards science. Several such instruments exist already (see for example the references given in the discussion), but with two serious constraints. First of all, as Osborne *et al.* (2003) have pointed out, the concept of attitudes is often poorly articulated and not well understood. Secondly, as has been a main concern for Munby (1982, 1997) and Gardner (1975, 1995, and 1996), attitude measures often have poor psychometric quality. The problem, it seems, results from a tradition for measuring that is rather 'pragmatic', not taking into account the difficulty of understanding a complicated psychological construct. Science educators often develop measures for a different purpose than for exploring the constructs themselves, and validation of the test often becomes a subordinate matter. We discuss each of these problems in more detail below.

Defining attitudes towards science

A problem that has been raised by those studying attitudes towards science (e.g. Germann, 1988; Francis & Greer, 1999; Osborne *et al*., 2003) is the definition of *attitude* itself. There seems to be many concepts that relate to attitudes that may or may not be included in their definition; e.g. feelings, motivation, enjoyment, affects, self-esteem etc. A common definition has involved describing attitudes as including the three components of *cognition*, *affect* and *behaviour* (e.g. Rajecki, 1990; Bagozzi & Burnkrant, 1979; McGuire, 1985). Reid (2006) provides a clear definition of these components:

> '(1) a knowledge about the object, the beliefs, ideas component (Cognitive);
> (2) a feeling about the object, like or dislike component (Affective); and
> (3) a tendency-towards-action, the objective component (Behavioural).'

In many ways, this seems a sensible view of attitudes because these components are so closely linked together. For example, we know about science and therefore have a feeling or an opinion about it that may cause us to take some actions.

Other researchers have suggested that the three components should be treated more independently, and that attitudes should be viewed in a narrower way, as the basis for 'evaluative judgements' (Ajzen, 2001; Crano & Prislin, 2006). When we have an attitude, we judge something along emotional dimensions, such as good or bad, harmful or beneficial, pleasant or unpleasant, important or unimportant. It is important to notice that these evaluative judgements are always towards something, often called the *attitude object* (Crano & Prislin, 2006).

This narrower conceptualisation can be used to clarify the definition of attitude. For example, asking about someone's attitude towards an object is, in principle, to ask how they judge the object. This definition makes clear that we are looking for something different from general affects, such as moods (e.g. being sad or happy) and emotions (e.g. fear and anger) (Ajzen, 2001). It also makes clear the distinction between attitude and behaviour. It is perhaps more difficult to separate the other affective and cognitive concepts. Although some researchers have defined attitude solely in terms the affective component (Germann, 1988; George, 2000), Fishbein & Ajzen (1975) viewed attitudes as being formed spontaneously and inevitably as individuals form beliefs about the attributes of an object. Attitudes, or the affective component of attitudes, are therefore linked to these beliefs that a person holds. Therefore, the definition for attitude that we use for this study is that it is *the feelings that a person has about an object, based on their beliefs about that object*.

Following this definition of attitudes, we can view an attitude towards science measure as a way of mapping students' cognitive and emotional opinions about various aspects of science. A necessary starting point is then to identify what objects we are focusing on. Commonly, distinctions are made between science at school, 'real' science and science in society. Each of these may be split into more detailed objects, which again may be characterised with a range of attributes. For example, school science includes sub-objects such as the science teacher, the science classroom and the science content. Each of these objects has attributes that may be judged along various dimensions. The science teacher, for example, may be characterised by ways of teaching or ways of relating to children and these may be something the students think of as good or bad, pleasant or unpleasant, interesting or uninteresting. Attitude theory (Ajzen 2001; Crano & Prislin, 2006) claims that attitudes about an object may be added up, based on attitudes towards the various attributes. In measuring attitudes therefore, we need to decide on what 'level' we are operating at. Is it meaningful for us to make one attitude scale towards science, or should this be broken down to several sub-scales? An answer to this must be based not only on our own understanding and conceptualisation of science, but also on pupil data, i.e. how the concepts associated with attitudes towards science are organised in the pupils' mind.

Attitude measures and their problems

Types of attitude measures

Osborne *et al.* (2003) and Gardner (1975) reviewed the numerous approaches to the measurement of attitudes, listing the following five main methods:

Preference ranking: This is an easy-to-use method where students simply rank their liking of school subjects. It is effective for answering the question 'How popular is science compared to other subjects?', but as it is a relative scale, is unsuitable for measuring attitude change.

Attitude scales: This is probably the most common method of measuring attitudes and occurs in a variety of forms. Differential (Thurstone-type) scales involve students choosing statements on a continuum that best reflect their attitudes. Semantic differential scales require students to rate a particular object (e.g. science lessons) according to a number of bipolar adjectives (e.g. good/bad, interesting/dull). More commonly, summated rating scales are used which consist of Likert scale items. Students respond to a number of statements that relate to the same construct (usually choosing from a five-point score such as 'strongly agree, agree, neither agree nor disagree, disagree, strongly disagree). The use of more than one response for the same construct greatly increases the reliability of the summated rating scores. However, there are many potential weaknesses with attitude scales which are discussed later on in this paper.

Interest inventories: This method requires students to choose the items that they are interested in from a list. Osborne *et al.* (2003) commented that *'such inventories are generally restricted to their specific focus, yielding only a limited view of what may or may not be formative on attitudes to science.'*

Subject enrolment: This method involves the collection of data on enrolment in various subjects. Both Osborne *et al.* (2003) and Gardner (1975) comment on the limitations of this method as a measure of interest in science, as subject choice can be influenced by a number of other factors including gender identity and economic factors.

Qualitative methods: Although limited in number, a few studies explore attitudes using student interviews and focus group interviews. What these methods lack in the ability to generalise the findings, they make up for in the richness of understanding that they offer.

In the present study, we developed and used attitude scales to measure pupils' attitudes towards science. As mentioned above, a major justification for using an attitude scale is the use of more than one question to measure the same construct to greatly increase reliability (Gardner, 1996). In addition, such scales are relatively simple to use, in terms of using them in questionnaires and distributing them to respondents. Many attitude scales have been used in the past for research on science education, and we discuss at the end of the paper whether some of these existing measures would have been suitable for our use.

Attitude scales in science education: a critique

Although there are advantages to using attitude scales to examine attitudes towards science, various studies have identified problems and weaknesses with many existing attitude measurements (for example Germann, 1988; Gardner, 1996; Munby, 1997; Francis & Greer, 1999; Bennett, 2001; Osborne *et al.*, 2003; Reid, 2006). Firstly, there has been a lack of clarity over the last thirty years about what is actually being measured when we measure attitude towards science (Osborne *et al.*, 2003). As discussed in the previous section, there is lack of clarity over the term *attitude*. The term *science* is a little less problematic but there is still a need to define whether we are looking at, for example, students' attitudes towards science in schools, students' attitudes towards science outside of school or students' attitudes towards scientists, all of which may vary considerably (Ramsden, 1998).

The lack of clarity and definition of what is being measured is therefore likely to lead to problems. When there is no clear definition of the underlying construct that is being measured, it is likely that disparate items may be put together in the attitude scale. They may display a common theme (e.g. attitudes towards science) but not a common construct (e.g. someone's attitude towards science in school may be very different to their attitude towards scientists outside school; Gardner, 1996). It would therefore be incorrect to include items from different constructs in the same scale, however Gardner (1996) cites cases where this has indeed been done. Similarly, Gardner also cites cases where researchers have clearly defined individual constructs but have added the scores from the individual constructs together, 'breaking a fundamental principle of psychometrics … people with the same score on a scale ought to be psychologically similar to each other' (Gardner, 1996). A neutral score from two combined constructs could be produced from a positive score on one and a negative score on the other or a neutral score on both. The lack of clarity and definition of constructs may also lead to a lack of consistency between the many instruments that exist to measure attitudes towards science, making comparison between studies impossible (Germann, 1988; Bennett, 2001).

A related criticism that is highlighted in the literature (Gardner, 1975 and 1995; Munby, 1983; Schibeci, 1984; Osborne *et al.*, 2003; Bennett, 2001; Germann, 1988) is that attitude measures can in fact be of poor psychometric quality. In order to demonstrate this quality, an instrument needs to be statistically *internally consistent* and *unidimensional*. Many studies fail to provide evidence of these psychometric traits or wrongly assume that internal consistency implies unidimensionality (Gardner, 1995). Cronbach α is commonly used as a measure of internal consistency. By definition the items in a unidimensional scale all measure the same construct so it follows that they will be internally consistent. However, it does not follow that internally consistent scales are unidimensional, as they may consist of more than one factor. It is therefore important to use a technique such as factor analysis to confirm the unidimensionality of a scale.

Failure to properly address construct validity (the extent to which a scale represents what it claims to represent) is also a threat to good psychometric quality and there is a danger of ignoring validity in light of support from high consistency or reliability. There are no set techniques to follow in order to demonstrate validity, but rather it is a case of amassing evidence from a selection of available techniques (Henerson *et al*., 1987 and Munby, 1997). Munby (1997) takes this further by stressing the importance of including psychometric evidence of validity in addition to non-psychometric evidence. There appears to be some lack of consensus over the ways in which we might demonstrate good validity. A common method employed is the panel method, where a panel of judges judge the validity of each item. Munby (1983 and 1997), however questions the assumption held in this technique that the meaning of the items for the judges is the same as it is for the respondents. Osbourne *et al* (2003), Oppenheim (1992) and Bennett (2001) suggest that validity can be obtained by deriving items from students' answers to free response questions. Validity can also be demonstrated by asking staff who know the students and/or the students themselves to comment on the results of an attitudinal scale, to see if they match their own opinions (Bennett, 2001). An alternative method is to seek construct validity through theoretical foundation, i.e. to use relevant theory as a base for developing and evaluating the test.

Psychometric approaches to validity include the calculation of correlation coefficients in order to demonstrate convergent and divergent validity (i.e. theoretically similar items should converge and theoretically dissimilar constructs and items should be discriminating) (Henerson, 1987; Trochim, 2002). Similarly Munby (1997) suggests using factor analysis to show that conceptually formed scales do in fact match with empirically produced factors and that when a scale has been used in more than one study, a repeated factor analysis on the new data can be used to confirm validity. Concurrent validity can be demonstrated by confirming whether the results of the scale in question correlate with a well established scale that claims to represent the same construct (Henerson, 1987), also giving additional evidence of construct validity. If it is important that a scale predicts future behaviour, then it is also important to demonstrate predictive validity by demonstrating that a scale that claims to predict a particular behaviour does in fact do that (for example does a scale that claims to measure future participation in science actually correlate with reality in the future?).

Therefore, from the above critique, we can put forward the following guidelines on how best to formulate an attitude measure:

- Clear descriptions need to be put forward for the constructs that one wishes to measure.
- Care needs to be taken when separate constructs are combined to form one scale, with justification that these constructs are closely related.
- Reliability of the measure needs to be demonstrated by confirming the internal consistency of the construct (e.g. by use of Cronbach alpha) <u>and</u> by confirming unidimensionality (e.g. by using factor analysis).
- Validity needs to be demonstrated by the use of more than one method, including the use of psychometric techniques.

We will refer to these guidelines as we describe the development of attitudes to science measures that we carried out in this study.

Developing attitudes to science measures

The attitudes to science measures described in this paper were developed for a study carried out on behalf of the Institute of Physics in the UK. This study involved evaluating the impact of 'Lab in a Lorry', a mobile laboratory that visited schools and used to demonstrate a series of experiments to pupils aged 11 to 14. The aim of this initiative was to encourage future participation of pupils in the sciences[1].

As part of this study, the following areas of attitudes to science were focussed upon as being important: Learning science in school, Practical work in science, Science outside of school, Importance of science, Self-concept in science, and Future participation in science. In addition, attitude to school generally was included, in order to find out how variations in the above science-related attitudes were related to this more general attitude. All the attitude areas listed, with the exceptions of attitude towards school, were chosen as areas that could possibly be affected by an initiative such as Lab in a Lorry. As a result, other possible influences on attitude to science were not included as part of this study, for example the influence of teachers as highlighted by Osborne *et al*. (2003).

At this point, as suggested by the above guidelines, let us be more specific about what we meant by the above constructs. The first three constructs aimed to examine pupils' attitudes towards science learning activities in different contexts (in the classroom, more specifically in practicals, and outside the classroom). It was believed that each of these contexts represented meaningful 'objects' that students were likely to have

[1] Further information of Lab in a Lorry can be obtained from the website www.labinalorry.org.uk

formed beliefs about. The next construct aimed to examine pupils' belief in the value of science in a wider social context. The last two constructs differed somewhat from the others in that the pupil themselves were part of the attitude-object. Self-concept is based on beliefs about one's own ability to master school science, which in turn is believed to form attitudes towards the subject. Future participation is similarly regarded as the students' attitude towards engaging more with science in the future.

Having defined the areas of attitude to science to be included in our study, the next step was to put together suitable measures for the above constructs. We adopted a Likert scale format, with each measure being made up of a series of statements relating to the above constructs. Respondents would be asked to state their level of agreement to the statements by choosing one response from a number of alternatives. At the pilot stage of the development of the attitude measures, a choice from the following four responses was given for each statement: 'Strongly agree', 'Agree', 'Disagree' and 'Strongly disagree'. For the actual statements making up each measure, they were made to capture various attributes of the attitude object and express different evaluative dimensions. Having a limited set of meaningful (to the pupils) statements was regarded as crucial. Some statements were therefore adopted from existing questionnaires which have been proven to work with pupils. These included some items from the Relevance of Science Education (ROSE) questionnaire, the 2003 PISA questionnaire and items from the attitude to science for 5 to 11 year olds, developed by Pell & Jarvis (2001). All statements were assessed by use of criteria suggested by Crocker & Algina (1986).

Following this formulation of the items for the attitude measures, we needed to pilot the attitude measures to check (i) the internal statistical reliability of the different measures, and (ii) use factor analysis to check whether the measures themselves would in fact be unidimensional, that the items that we had put together would actually measure the same thing. Therefore, the constructed measures were put together into a paper questionnaire, which in turn was given out to 44 Year 8 and Year 9 pupils (12 to 14 year olds) from the same secondary school in the North East of England. Using the statistical package SPSS to carry out reliability calculations and factor analysis on the data collected, items that reduced the internal reliability of attitude measures or did not group together with other items were identified. These items were either removed from the measures, or their wording was modified. In addition, it was found during this trial that pupils sometimes tried to provide an answer between 'Agree' and 'Disagree' (e.g. ticking both responses, or placing a tick between the two responses). Therefore, following this trial, the possible responses were extended to a five-point scale, including 'Neither agree nor disagree' as the middle response.

Analysing the results from the attitude to science measures

In describing the trialling of the attitude measures in the previous section, we did not provide any details of the results of the reliability calculations and the factor analysis. Rather we will establish the reliability and unidimensionality of the measures in the context of the larger study that was carried out following this initial trial.

This larger study was part of the evaluation of Lab in a Lorry, described in the previous section. This involved measuring the attitudes of Year 7, Year 8 and Year 9[2] pupils in five different secondary schools, prior to the visit of Lab in a Lorry to their school. Three of these schools were located in the North East of England (but different to the school used in the trialling of the measures), one school located in the South West of England and one school in the South East.

A paper questionnaire with the attitudes to science measures, modified as a result of the trial, was given out to pupils in these schools. This questionnaire was given out twice to pupils, two weeks before the visit of Lab in a Lorry, and two weeks after. Teachers were asked to give out questionnaires to both pupils who would visit the lorry, and to those that would not. Therefore, pre- and post-measures of attitudes to science for two groups of pupils were obtained. Altogether, 932 pupils completed the questionnaire for the pre-measure, and 668 pupils completed it for the post-measure.

Prior to the analysis of the attitude data, all the responses were coded numerically. Initially, the responses were coded as ‘Strongly agree’ = 5, ‘Agree’ = 4, ‘Neither agree nor disagree’ = 3, ‘Disagree’ = 2 and ‘Strongly disagree’ = 1. Subsequently, prior to the reliability analysis of the data, the responses were reverse coded for negatively phrased items.

(a) Factor analysis of the attitude measures – pre-measure data

We began the analysis of the data obtained from this larger study by examining the dimensions obtained from factor analysis of the data. First of all, we used principle components factor analysis on all the data in order to extract the appropriate number of factors. Eight factors were obtained with eigenvalues greater than 1. However, Kline (1994) highlighted that this method of determining the number of factors can overestimate the number of factors. An alternative approach to determine the appropriate number of factors is to examine the scree plot produced by the analysis. The corresponding scree plot from the pre-measure data suggested an extraction of something like four factors, although this was not so clear from the plot (**Figure 1**).

[Insert Figure 1 about here]

Therefore, based on our theoretical starting point of seven areas of attitude, we actually started with principle axis factoring using oblique Direct Oblimin rotation on seven factors. These results, with loading less than 0.3 not being shown, are given in **Table 1**. The items making up the various attitude measures are given in the left-hand column of the table. The items pertaining to each attitude construct were grouped together in the original questionnaire, and the order of the items given in **Table 1** is in the same order that they appeared in the questionnaire. The ordering of the attitude constructs in **Table 1** is Learning science in school, Self-concept in science, Practical work in science, Science outside of school, Future participation in science, Importance of science, and General attitude towards school. The items in **Table 1** are separated out accordingly into these constructs.

[2] These are the first three years of secondary schooling in England.

[Insert Table 1 about here]

In the seven-factor solution to the analysis, the extracted factors did indeed correspond to the seven areas of attitudes to science that we introduced at the beginning of the study. This provided some confirmation that we were dealing with distinct areas of attitude, and each of these areas was unidimensional. However, one possible problem was with the item 'Scientists have exciting jobs' from the Importance of science group of statements, which did not load on any of the factors. It seemed reasonable from the wording of the statement that this item was not actually about importance of science. Therefore, this item was removed from our list of statements.

To provide further confirmation of the unidimensionality of each attitude measure, principle components factor analysis was carried out on each group of statements separately. In each case, only one factor was extracted. Once again, this provided confirmation that each set of attitude statements was measuring one attitude construct only.

As we identified above though, the scree plot identified around four factors to extract, rather than seven. Repeating the principle axis factoring with oblique Direct Oblimin rotation on four factors, it was found that three areas of attitude, Learning science in school, Science outside of school and Future participation in science, were placed in one factor. In addition, the group of statements pertaining to Importance of Science did not load on any of the four factors. The other three areas of attitude were still identified as individual factors. These results for the four-factor solution suggested that the three areas of attitude that were grouped together were in fact closely correlated, and perhaps make up a more general attitude measure pertaining to an interest in science. To confirm this, principle components factor analysis was carried out on the data from these three areas of attitude only. The scree plot obtained (**Figure 2**) did indeed suggest a single overall factor.

[Insert Figure 2 about here]

(b) Factor analysis of the attitude measures – post-measure data

To confirm the results obtained from the pre-measure data, factor analysis was also carried out on the post-measure data. Principle components analysis of all the post-measure data gave eight factors with eigenvalues greater than 1, and provided the scree plot shown in **Figure 3**.

[Insert Figure 3 about here]

Once again, the plot suggested the extraction of four factors. However, we again started with an extraction of seven factors. The results of principle axis factoring with oblique Direct Oblimin rotation on these seven factors are shown in **Table 2**.

[Insert Table 2 about here]

Although the seven-factor solution identified the seven theoretical constructs that we started off with, the loadings on the Importance of Science factor were relatively small. This indicated that this factor was not well defined as an individual construct. The results also showed that in this case, some of the Future participation in science items loaded more on the Science outside school factor. Again, this might have indicated that these two areas of attitude to science were quite closely related. Carrying out principle components factor analysis on each of the attitude areas separately, we once again found that only one factor was extracted in each case. This once again confirmed that each of our theoretical constructs were unidimensional.

We now carried out principle axis factor analysis with oblique Direct Oblimin rotation, this time with four factors. We found that similar results were obtained as for the pre-measure data, with the three areas of attitude Learning science in school, Science outside of school and Future participation in science, being placed in one factor. Once again, principle components factor analysis was carried out on the data from these three areas of attitude only. The scree plot obtained (**Figure 4**) did again suggest a single overall factor incorporating these areas of attitude.

[Insert Figure 4 about here]

In addition, two of the Importance of Science statements loaded on this combined factor, although one of these loadings was relatively weak at around 0.3. Therefore, as for the pre-measure data, we considered the Importance of Science factor to be separate to this combined attitude factor. The other three areas of attitude were again identified as individual factors.

Therefore, from this part of the study concerning the factor analysis of the attitude data, we drew the following conclusions:

- The statements of attitude in each of our seven constructs were each found to be unidimensional in each case.
- Principle component factor analysis suggested that three of the factors, Learning science in school, Science outside of school and Future participation in science, combined to form a more general factor, which we called the *Combined interest in science* factor.

(c) Reliability analysis of the attitude measures

Having established the unidimensionality of the various attitudes to science measures, we now examined the internal reliability of these measures. **Table 3** below gives the Cronbach α values for each measure, both for the pre- and post-measure data. Prior to carrying out the reliability calculations, all negatively worded items were reverse coded.

[Insert Table 3 about here]

The Combined interest in science measure (incorporating the Learning science in school, Science outside of school and Future participation in science measures) is also included in the above table. For all the attitudes to science measures, the internal reliability was calculated to be above the threshold of 0.7 for both the pre- and post-measure data. However, we can see that the reliability was lowest for the Importance of Science measure. This indicated that improvements to this measure (e.g. modifying items or adding new ones) would perhaps be required in the future.

In addition to examining the internal reliability of each measure, we also checked the spread of each measure in terms of mean values and standard deviations. These results are summarised in **Table 4** below.

[Insert Table 4 about here]

From these results, we identified that the Practical work in science measure had the highest average of around 4 on the five-point scale. The fact that this measure was closer to the maximum value of the scale, and that this measure had lower standard deviations than most of the other measures, indicated that a ceiling effect might be acting on this measure. Plotting histograms of this measure's data confirmed this. Therefore, another future improvement that we would suggest would be to add other items to this particular measure, lowering this mean score and thus reduce the ceiling effect.

(d) Correlation of attitude measures

We conclude this analysis of the attitude measures by examining the correlations between the different constructs. The Pearson correlation coefficients between each of the seven individual measures are given in **Tables 5** and **6** for pre- and post-measure data respectively. The Combined interest in science measure is not included, as we know that this will correlate highly with the individual measures that comprise it.

[Insert Table 5 about here]
[Insert Table 6 about here]

In both tables, the correlations between the Learning science in school, Science outside of school and Future participation in science measures were amongst the highest in the tables, being in the range of 0.6 to 0.7. These high correlations confirmed our previous conclusions that these three measures were closely related, and could in fact be combined into one Combined interest in science measure.

Discussion

The main aim of this study was to describe the development of measures for attitudes towards science. In doing so, we defined in advance the constructs to be measured, and outlined clearly the process of validating the measures, in this case using factor analysis. Of course, a question we needed to ask was whether there were already suitable attitude measures, with well defined and validated constructs, that we could have used instead of developing our own. Therefore, we begin this discussion by looking at the suitability of some other published attitudes to science measures.

As discussed at the beginning of the paper, problems with some existing attitude measures have been raised in the literature. Munby (1983 and 1997) has criticised the Science Attitude Instrument developed by Moore & Sutman (1970) and Moore & Foy (1997) in terms of the validity of its underlying constructs. Gardner (1996) has also provided examples of attitudes towards science measures that do not define the underlying concepts, or examine the unidimensionality of the constructs. One example that he does provide for good practice in developing such measures is that of Coulson (1992), although this measure was developed for early childhood educators rather than for school pupils.

Napier & Riley (1985) used existing items from the National Assessment of Educational Progress survey in the United States to develop attitude towards science measures. They did carry out factor analysis to obtain a number of unidimensional measures for a number of science-related attitudes. These included science enjoyment in the classroom and anxiety in the science classroom, which could perhaps have been appropriate for our use. However, the wording of some of the items involved (e.g. 'How often do you like to go to science class') did not appear to be appropriate for use with younger, non-American school pupils.

Germann (1988) also developed a reliable, unidimensional measure for attitudes towards science in school. With Cronbach α reliability values of 0.95 and above, this measure would certainly seem to be an appropriate measure that we could have used. The only reason that it was inappropriate for our particular use was that we wanted to separate the constructs of attitude towards science in and out of school. Some of Germann's items (e.g. 'Science is interesting to me and I enjoy it', 'When I hear the word science, I have a feeling of dislike') seemed not to be specific enough in this respect.

The Attitudes towards Science Inventory, developed by Gogolin & Swartz (1992), once again examined relevant constructs such as enjoyment of science, self-concept in science and value of science in society. In this case however, although reliability measures and item-to-scale correlations were given for each construct, no checks of unidimensionality of the scales were provided in their paper. Pell & Jarvis (2001) did check for unidimensionality in their development of attitudes towards science measures for children aged 5 to 11 years. They identified three constructs: a science enthusiasm scale, a social context of science scale and science is a difficult subject scale. Because of the suitability of the items for younger school pupils, some of Pell and Jarvis' items were used in the present study, in particular for our Science outside of school measure. However, we chose not to use all of their items, firstly because we wanted once again to separate out items pertaining to science in and out of school, and secondly because the reliability values for their scales were close to or below the threshold of $\alpha = 0.7$.

Finally, Francis & Greer (1999) developed a measure to particularly examine the affective domain of attitude towards science. They used factor analysis to establish a unidimensional measure which gave high reliability values ($\alpha \approx 0.9$). However, the underlying constructs making up this measure were not defined, and appeared in fact to be a mix of what we have termed as importance of science, attitude towards science in school, future intentions in science and self-concept in science. Therefore, once again, we chose not to use this measure for our particular study.

Our reasons for not using available measures for attitudes towards science were therefore just as much to do with our specific requirements in using these measures, as well as drawbacks in the development of some of these. Our wish to examine specific constructs associated with attitudes towards science, rather to examine a general attitude towards science, necessitated the development of our particular measures.

In fact, we view this approach of starting with particular constructs as a strength of this study. Not only are we dealing with the concern of Gardner (1996) that different constructs are being mixed together in the same attitude scale, but it also allows us to build up the attitude scales step by step. It may perhaps be that separate constructs are closely correlated and are effectively part of a more general attitude scale, but we only combine the constructs when this has been validated through responses to the scales. The approach also allows us to identify particular weaknesses and gaps in the attitude scales. By dealing with the constructs separately, we could see that there were weaknesses in our Importance of science measure. We have also acknowledged that we have not examined other important influences on pupil attitudes towards science, such as their views on their science teachers. We can therefore include these as other separate constructs in our studies in the future.

A possible weakness that can be put forward with the present study is that further validation of the various attitude measures could be carried out. Demonstrating concurrent validity would have further strengthened the validity of the measures but in this instance we did not wish to overload the pupils with a lengthy questionnaire. This is something that we can address in future studies. The criteria that we put forward for developing attitude measures suggested that different methods of validation be used. The results of the factor analyses in Tables 2 and 3 confirmed that our conceptually formed factors matched with empirically produced scales (i.e. the components formed in the way we would have expected). These results also confirmed convergent and divergent validity at item level (items that belonged to the same scale are highly correlated with themselves and divergent from those in different scales).

However, we could have also examined whether the attitude measures had predictive validity in describing expected behaviour from pupils. For example, commonly observed patterns in pupils' attitudes towards science are that they decline over the period of their schooling, and that the attitudes of female pupils are less positive than those of the male pupils. Having developed our attitudes towards science measures in this paper, we will explore in a future publication whether these patterns are highlighted by our measures.

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For copies of the questionnaires used in this research, please contact Dr Patrick Barmby at the corresponding address or e-mail provided.

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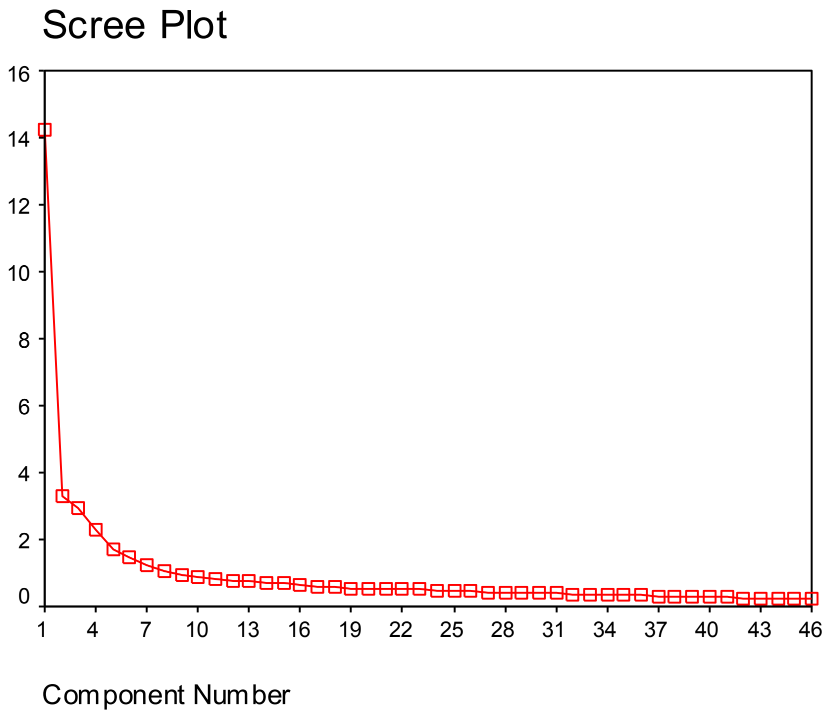

Figure 1. Scree plot from the factor analysis of the pre-measure data

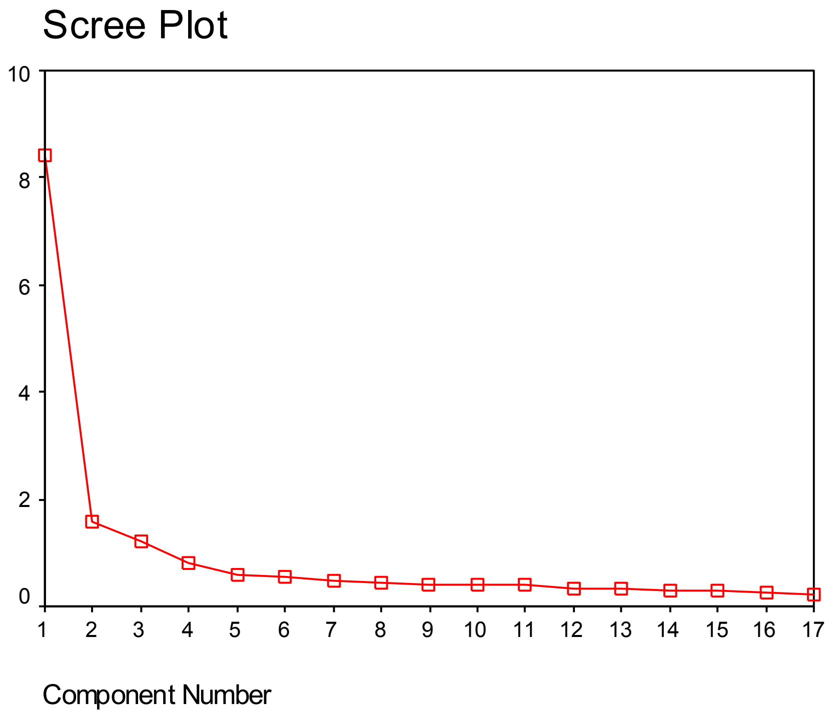

Figure 2. Scree plot for factor analysis on of pre-measure data: Three areas of attitude only

Table 1. Factor analysis results for the pre-measure data

	Components						
Attitude Statements	1	2	3	4	5	6	7
We learn interesting things in science lessons.					-0.580		
I look forward to my science lessons.					-0.629		
Science lessons are exciting.					-0.553		
I would like to do more science at school.					-0.450		
I like Science better than most other subjects at school.					-0.481		0.308
Science is boring.					0.522		
I find science difficult.				0.749			
I am just not good at Science.				0.722			
I get good marks in Science.				-0.670			
I learn Science quickly.				-0.593			
Science is one of my best subjects.				-0.429	-0.364		
I feel helpless when doing Science.				0.555			
In my Science class, I understand everything.				-0.541			
Practical work in science is exciting.		0.632					
I like science practical work because you don’t know what will happen.		0.542					
Practical work in science is good because I can work with my friends.		0.411					
I like practical work in science because I can decide what to do myself.		0.394					
I would like more practical work in my science lessons.		0.819					
We learn science better when we do practical work.		0.692					
I look forward to doing science practicals.		0.778					
Practical work in science is boring.		-0.666					
I would like to join a science club.	0.449						
I like watching science programmes on TV.	0.622						
I like to visit science museums.	0.637						
I would like to do more science activities outside school.	0.615						
I like reading science magazines and books.	0.619						
It is exciting to learn about new things happening in science.	0.443				-0.304		

Table 1. Factor analysis results for the pre-measure data continued

	Components						
Attitude Statements	1	2	3	4	5	6	7
I would like to study more science in the future.							0.396
I would like to study science at university.							0.620
I would like to have a job working with science.							0.799
I would like to become a science teacher.							0.577
I would like to become a scientist.							0.731
Science and technology is important for society.						0.707	
Science and technology makes our lives easier and more comfortable.						0.769	
The benefits of science are greater than the harmful effects.						0.550	
Science and technology are helping the poor.						0.481	
There are many exciting things happening in science and technology.						0.485	
Scientists have exciting jobs.							
I really like school.			0.805				
I would recommend this school.			0.673				
I find school boring.			-0.719				
I feel that I belong in this school.			0.532				
Most of the time I wish I wasn’t in school at all.			-0.572				
I get on well with most of my teachers.			0.591				
I am normally happy when I am in school.			0.724				
I work as hard as I can in school.			0.388				

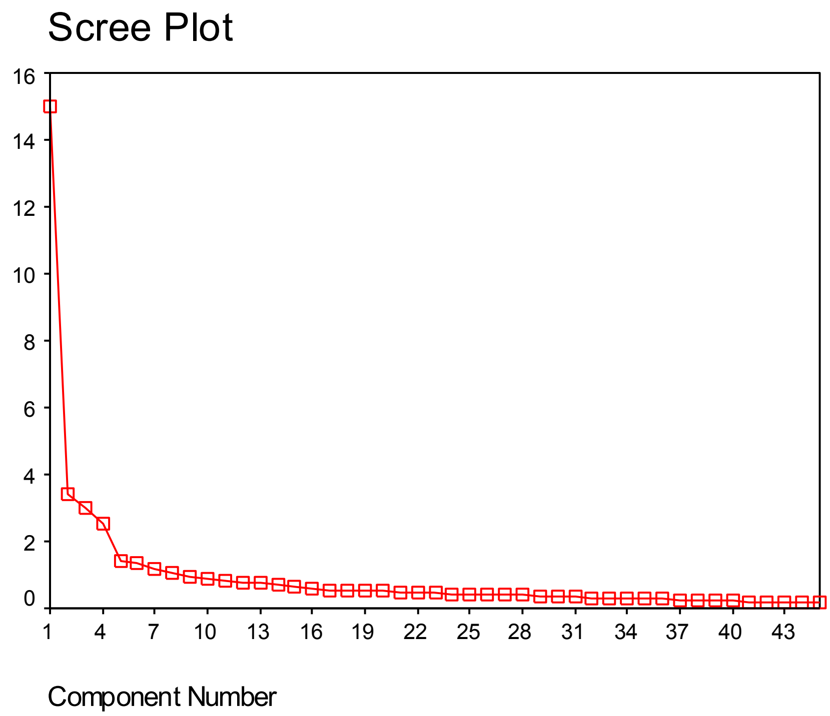

Figure 3. Scree plot for factor analysis of post-measure data

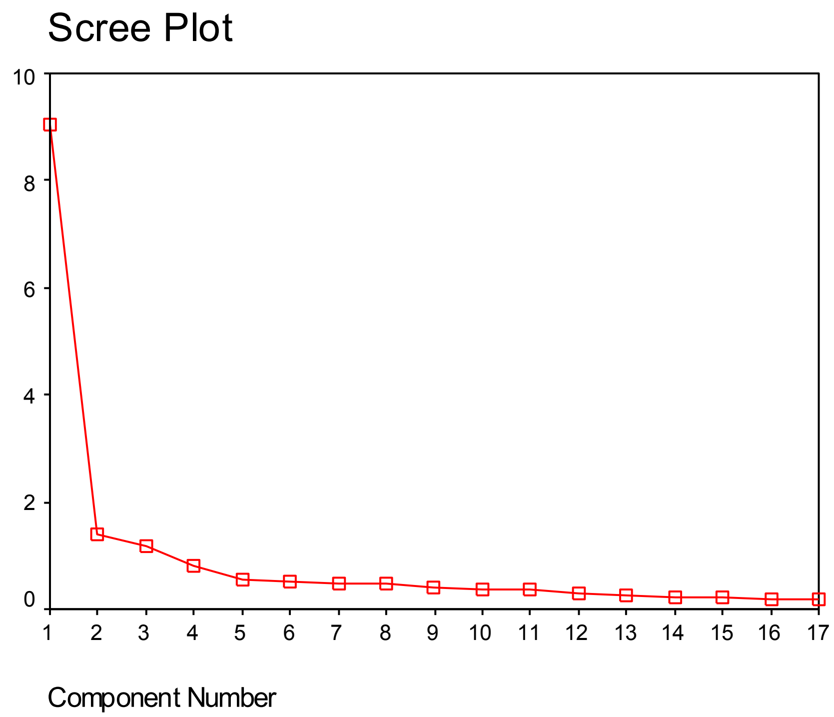

Figure 4. Scree plot for factor analysis on of post-measure data: Three areas of attitude only

Table 2. Factor analysis results for the post-measure data

	Components						
Attitude Statements	1	2	3	4	5	6	7
We learn interesting things in science lessons.					-0.589		
I look forward to my science lessons.					-0.845		
Science lessons are exciting.					-0.767		
I would like to do more science at school.					-0.745		
I like Science better than most other subjects at school.					-0.726		
Science is boring.					0.577		
I find science difficult.				0.694			
I am just not good at Science.				0.744			
I get good marks in Science.				-0.641			
I learn Science quickly.				-0.670			
Science is one of my best subjects.				-0.370	-0.481		
I feel helpless when doing Science.				0.506			
In my Science class, I understand everything.				-0.572			
Practical work in science is exciting.		0.675					
I like science practical work because you don't know what will happen.		0.693					
Practical work in science is good because I can work with my friends.		0.540					
I like practical work in science because I can decide what to do myself.		0.542					
I would like more practical work in my science lessons.		0.845					
We learn science better when we do practical work.		0.774					
I look forward to doing science practicals.		0.810					
Practical work in science is boring.		-0.763					
I would like to join a science club.	0.711						
I like watching science programmes on TV.	0.579						
I like to visit science museums.	0.573						
I would like to do more science activities outside school.	0.638						
I like reading science magazines and books.	0.704						
It is exciting to learn about new things happening in science.	0.445						

Table 2. Factor analysis results for the post-measure data continued

	Components						
Attitude Statements	1	2	3	4	5	6	7
I would like to study more science in the future.							-0.614
I would like to study science at university.							-0.774
I would like to have a job working with science.							-0.778
I would like to become a science teacher.	0.400						
I would like to become a scientist.	0.440						-0.452
Science and technology is important for society.						0.405	
Science and technology makes our lives easier and more comfortable.						0.329	
The benefits of science are greater than the harmful effects.						0.346	
Science and technology are helping the poor.							
There are many exciting things happening in science and technology.					-0.353		
I really like school.			0.772				
I would recommend this school.			0.627				
I find school boring.			-0.683				
I feel that I belong in this school.			0.597				
Most of the time I wish I wasn't in school at all.			-0.592				
I get on well with most of my teachers.			0.503				
I am normally happy when I am in school.			0.766				
I work as hard as I can in school.			0.377				

Table 3. Cronbach α reliability values for each attitude measure

Measure	Cronbach α (pre-measure)	Cronbach α (post-measure)
Learning science in school (6 items)	0.89	0.92
Self-concept in science (7 items)	0.85	0.85
Practical work in science (8 items)	0.85	0.89
Science outside of school (6 items)	0.88	0.87
Future participation in science (5 items)	0.86	0.88
Importance of science (5 items)	0.77	0.72
General attitude towards school (8 items)	0.85	0.85
Combined interest in science (17 items)	0.93	0.94

Table 4. Mean values and standard deviation of each attitude measure

	Pre-measure		Post-measure	
Measure	*Mean*	*SD*	*Mean*	*SD*
Learning science in school	3.38	0.82	3.06	0.97
Self-concept in science	3.41	0.70	3.24	0.75
Practical work in science	4.05	0.64	3.95	0.77
Science outside of school	2.75	0.93	2.64	0.92
Future participation in science	2.57	0.85	2.38	0.89
Importance of science	3.58	0.67	3.50	0.65
General attitude towards school	3.40	0.76	3.32	0.77
Combined interest in science	2.92	0.76	2.71	0.83

Table 5. Correlations between each attitude to science measure – pre-measure data

Measure	Self-concept in science	Practical work in science	Science outside of school	Future participation in science	Importance of science	General attitude towards school
Learning science in school	0.616	0.402	0.669	0.598	0.476	0.425
Self-concept in science		0.322	0.464	0.499	0.391	0.327
Practical work in science			0.336	0.312	0.455	0.283
Science outside of school				0.661	0.463	0.446
Future participation in science					0.477	0.341
Importance of science						0.390

Table 6. Correlations between each attitude to science measure – post-measure data

Measure	Self-concept in science	Practical work in science	Science outside of school	Future participation in science	Importance of science	General attitude towards school
Learning science in school	0.574	0.458	0.696	0.662	0.558	0.426
Self-concept in science		0.323	0.439	0.467	0.368	0.304
Practical work in science			0.401	0.337	0.488	0.291
Science outside of school				0.691	0.512	0.414
Future participation in science					0.468	0.303
Importance of science						0.351